BREAKING THE SIZE BARRIER IN CONTAINERIZATION--

"WASHED" EUCALYPTUS SEEDLINGS 1/

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Abstract.--Root washing is the key operation in a containerization system to produce seedlings with rooting volumes larger than we could afford to handle as bulky plugs. Gentle water jets wash away an erodible container medium permitting recovery of root systems complete and undamaged. Seedlings are handled as compact bare-root stock and containers and media are reused. In 11 outplanting trials, washed seedlings averaged 96.6 percent survival compared to 97.4 for plugs.

In the southern half of Florida we are working to create a new pulpwood resource by planting locally selected strains of the Australian species: Eucalyptus grandis, E. robusta, E. camaldulensis, and E. tereticornis. Survival averaged 85 percent for our first two planting seasons, and foot-per-month height growth is common during the first 2 years. But we have formidable problems, mainly in developing a containerization system capable of satisfying the demand for planting stock.

Technology and seed supplies for this effort are being developed through a research cooperative consisting of Container Corporation of America, the Florida Division of Forestry, Hudson Pulp & Paper Corp., International Paper Co., ITT Rayonier, Lykes Bros. Inc., and the U.S. Forest Service. Both the research cooperative and commercial planting started in 1972. Through July 1974, 396,000 seedlings have been raised to plant 900 acres. All seedlings have been container grown from genetically improved seed and outplanted with standard forest planting machines.

Eucalypts in Florida may already qualify as the largest containerized, machine-planted hardwood forestation effort in North America. Yet the planting figures are discouragingly modest compared to the existing need for hardwood fiber and the actual demand for planting stock. Nursery capacity currently hovers near 400,000 seedlings annually while actual demand is 1-3 million with potential demand for at least 5 million seedlings per year.

CONTAINER SIZE LIMITS SEEDLING SIZE

As we struggle to develop productive nursery techniques, we find the cultural needs of eucalyptus seedlings conflicting with economic and logistic constraints on producing and planting plugs. The consequential needs of our eucalyptus seedlings are described below.

Need for Summer Outplanting.--Eucalypts planted in Florida are subtropical hardwoods, evergreen, ever growing, and susceptible to frost as seedlings. They have no dormant or deciduous season to "anesthesize" them against the stresses of outplanting. Instead, they must be outplanted at the peak of their growth rate in the mid-90 degrees heat of June and July--the only months offering the essential combination of soil moisture adequate for planting plus sufficient time for seedlings to grow into hardier saplings before first frost.

Need for Large Seedlings.--Our summer planting experience indicates that eucalypts conform to the axiom of hardwood planting, the bigger the seedlings the better. Seedlings less than 6 inches tall sometimes seem literally cooked by solar heating and reflection from Florida's light-colored sand soils.

Despite outplanting during the summer rainy season, desiccation is the major threat to newly planted eucalypts. If the rainy season lapses for a week, as is not unusual, fresh planting beds rapidly dry to a depth of about

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4 inches. Plugs need to be about 5 inches long and outplanted with root collars about 2 inches below the soil surface in order to contact more persistent moisture at the bottom of the planting trench. Foot-tall seedlings at least 1/4 inch in diameter have well developed bark that guards against infection and heat girdling after deep planting.

The next threat is herbaceous competition which the eucalypts must overtop in the first 3 months. Large seedlings have a head start over small seedlings in overtopping both the weeds and the low lying ground frosts of the first winter.

Need for Low Seedbed Density.--Eucalyptus leaves are long and extremely intolerant of shading and crowding. Appropriate seedbed densities are 25-35 seedlings per square foot for plug volumes of 3-5 cubic inches. This means that we could utilize only every third hole in a Styroblock "2", or every third tube in a Leach tray, and books of Spencer-Lemaire "Fives" would have to be separated by dead spaces 4 inches wide.3/ This need for wide spacing means that with most container systems about 80 percent of our growing area is dead space, leaving only about 20 percent as actual soil surface to receive irrigation and liquid fertilizer. As leaves increase in size and number they create an umbrella effect, further reducing the proportion of irrigation and fertilization that finds the tiny soil surface of conventional plugs.

Need for Substantial Rooting Volume.--Eucalyptus seedlings achieve their celebrated growth rate with the aid of agressive roots that explore greater volumes of soil than seem indicated by shoot size. Natural seedlings have strong taproots and a few sprawling laterals that may extend several times longer than stem height. When root development is confined within containers and sculptured by air pruning, those solitary taproots and sparse laterals transform into dense mats of fibrous roots moulded in the exact size and shape of the container--the mass we call a plug.

But fibrous rooting does not obviate the need for containers with generous rooting volumes. For example, we easily grow seedlings 18 inches tall in 12 weeks in quart pots (57 cubic inches). But in 3-cubic-inch tubes a minimum acceptable outplanting height of 8 inches is achieved in 14-16 weeks only by forcing fertilization to the limits of burning plus large doses of good fortune.

3/Use of trade names is illustrative and does not constitute an endorsement by the U.S. Department of Agriculture.

The capability to grow seedlings in 12 weeks is important because it allows us to sow the nursery crop after the danger of last frost in early March and still be ready to outplant with the onset of summer rains in early June. A 12-week nursery season eliminates any need for greenhouses or other frost protection in the nursery and is well within the eucalypts' growth rate if given adequate rooting volume.

LARGER PLUGS ARE AN OBVIOUS ANSWER, BUT...

The seedlings' needs for wide spacing and generous rooting volume; the planting sites' threats of drought, weeds, and frost; the desirability of a 12-week nursery season: all these challenges can be met by simply growing large seedlings in large containers. How large?

Our estimate of desirable seedbed density, 25 seedlings per square foot, would call for individual cavities with soil surface areas of 2.4 x 2.4 inches. Such a grid of cavities would contain no dead space and would intercept all irrigation and fertilization applied over the seedbed.

A cavity depth of 5 inches would enable seedlings plunged 2 inches at outplanting to have their root tips just touching the bottoms of the planting machine trenches which average about 7 inches deep in Florida's sand soils.

If two sides of the cavity slope until they almost meet at the bottom, they form a drainage slit that retains rooting medium while allowing the roots themselves to grow down through the slit to air prune before they can J-root or spiral. The two sloping walls ease seedling extraction and the resultant wedge-shaped cavity has a volume of 14.4 cubic inches--over twice the volume of the largest plugs we have commercially planted in Florida and 3 to 5 times larger than plugs commonly produced for commercial forest planting.

How big can plugs be before they contain more peat, vermiculite, and other ingredients than we can afford to bury on the planting site? How big before their cumulative bulk is uneconomic to package and transport? How bulky can plugs be and still pile 2,000 of them on a planting machine (let alone on a hand planter) in order to make a complete lap of mile-long plantation rows? How large a plug can be efficiently stuffed into trenches opened by standard forest planting machines?

Different limits will be placed on plug size depending on the local cost of soil mix ingredients as well as the interest rates selected and the anticipated rotation age. But whatever the limit, it seems reasonable that eucalypts, and probably some other hardwoods, would benefit from rooting volumes larger than we can afford to handle as conventional plugs.

CONTAINERIZED ROOT SYSTEMS GET IT ALL TOGETHER

Is there a practical way to produce large seedlings in large containers without having to package, transport, and outplant large plugs? Perhaps there is if the dependability of container-grown stock is primarily attributable to the container and not to the plug per se.

The container's essential function is to confine all root development to a specific, compact volume from which we recover the entire root system undamaged. The plug merely packages that complete root system and, perhaps more importantly, preserves functional root-soil interfaces during transit and transplanting. But even with root-soil interfaces intact, seedlings must rapidly extend roots into the planting site or they will exhaust the tiny supply of water carried from the nursery in the plug. This critical ability for rapid root extension goes back to the complete, undamaged root system--a gift of the container that confined it, not the peat and vermiculite that packaged it.

Conversely, unreliable survival of bare-root stock is hardly explained by light packaging and absence of soil around the roots. It is more likely caused by incomplete, dys functional root systems damaged during wrenching and lifting from the seedbed.

COMBINING CONTAINERIZATION WITH BARE-ROOTING

If we could remove growing medium without injuring roots, we might confidently package, transport, and outplant container-grown seedlings just as we now handle bare-root stock. By thus eliminating plugs we could break the barrier on container size. The survivability and vigor of large seedlings from large containers would be combined with the convenience and economy of compact, lightweight bare-root stock. Both growing medium and containers would remain in the nursery for indefinite reuse, thereby spreading over many crops the cost of larger containers and medium to fill them.

That is my hypothesis and motivation for trying to team containerization with bare-rooting to produce large planting stock I call "washed" seedlings.

The production plan for washed seedlings is simple:

1. Confine root development within air-pruning containers until seedlings attain optimum condition for outplanting.

2. Wash away the container medium with gentle streams of water to recover the' root systems complete, undamaged, and bare-rooted.

3. Package, transport, and outplant the washed seedlings just like bare-root stock from open seedbeds.

Required development steps are to:

1. Define survival and growth over the range of expected planting conditions.

2. Find a rooting medium that is rapidly erodible by gentle streams of water applied in manageable volumes.

3. Develop a container that will hold the erodible medium against irrigation and rainfall while still permitting free drainage and root egress for air pruning.

4. Devise fertilizer prescriptions to grow quality seedlings in the erodible medium.

5. Develop operational systems for washing and recycling the growing medium.

WASHED SEEDLINGS SURVIVE WELL, BUT EARLY GROWTH LAGS SLIGHTLY

We planted a total of 11 trials of washed seedlings in 1964, '65, '71, and '73. Each of our four commercial eucalyptus species was planted in at least one trial. Soil moisture during establishment periods ran the gamut from extremely dry (Meskimen 1973) to flooded. For all 11 trials, survival of washed seedlings averaged 96.6 percent compared to 97.4 percent for the balled or plugged check seedlings. Washed seedlings survived 100 percent in 4 of the 11 trials.

We hand-planted in early trials using seedlings raised in quart pots, but in 1971 and 1973 trials we machine-planted stock raised in air-pruning containers with volumes of 1.8 and 5.8 cubic inches. For six machine planted trials, washed seedlings averaged 95.9 percent survival against 96.0 percent for plugs, with not a single statistically significant difference between survival of washed seedlings and plugs.

Washed seedlings usually grow slightly slower than plug stock during the first month or two after planting. The growth lag is normally only 0.1 or 0.2 foot but is often statistically significant due to the modest growth that even the plug seedlings make while becoming established. Combining all 11 planting trials at a mean age of 16 weeks after planting, washed seedlings averaged 2.4 feet of growth since planting compared to 2.7 feet for plug stock--a differential of about 11 percent. The lag fades as growth accelerates to around a foot per month in the third and fourth months after planting.

Trials to date have produced both washed and balled seedlings in unrealistically large containers like quart pots, or else in tubes less than half the size envisioned for washed stock. Survival data has been consistent regardless of container size, but the early growth lag deserves closer scrutiny in terms of initial size differences expected between plug seedlings from cavities of 3-5 cubic inches versus larger washed seedlings grown in containers at least three times larger.

WASHING CUTS SEEDLING WEIGHT 69 PERCENT, DOUBLES PACKAGE CAPACITY

The machine planting trial of 1973 used the most realistic container size to date. Seedlings grew in wedge-shaped cavities 5 inches deep and 1.2 x 2.2 inches in top cross section, with rooting volume of 5.8 cubic inches. I think this is near a practical maximum for plugs, though it is less than half the size I propose for washed seedlings.

Seedlings of five eucalyptus varieties grew to an average height of about 1 foot in 14 weeks in a mixture of peat and vermiculite.. We outplanted about 800 seedlings of each variety, half as plugs and half as washed stock. Irrigated to field capacity and ready for packing, plug seedlings weighed an average of 65 grams per seedling. In contrast, washed seedlings weighed only 20 grams per seedling or 69 percent less than plugs.

We packed seedlings horizontally in cartons, alternating root and shoot direction in layers for maximum capacity. Cartons held an average of 215 plug seedlings with a gross weight of 45 pounds compared to 425 washed seedlings at 37 pounds.

WASHING THE CONTAINER MEDIUM; AND CONTAINING THE WASHABLE MEDIUM

Peat-based growing mediums are not practical to wash. The eucalypts' profuse, containerized rooting habit binds the peat into a fibrous mass that is unerodible except by high-pressure water jets that undoubtedly injure the roots. Even at high pressure, exposure time is excessive and the quantity of water unmanageable.

The same difficulties probably exist with other fibrous organic media such as wood shavings, bagasse, pulps, and most barks. Equally unwashable are inorganic media like expanded perlite with pores large enough for tiny roots to penetrate. Pure fine sand is the most washable and cheapest medium we have found; but it is also very heavy and deficient in nutrient exchange capacity. An early study with seedlings in quart pots demonstrated the washability of pure sand, and the hazards of washing peat-based media. Sand-grown seedlings were washed clean in an average of 27 seconds with a hose and gentle water breaker. Seedlings grown in a 1:1 peat:sand mix required removal of the water breaker and exposure to the high-pressure hose stream for an average of 72 seconds. Outplanting survival averaged 98 percent for seedlings washed from pure sand, 96 percent for balled peat-sand check plants, and a significantly lower 82 percent for seedlings washed from peat-sand, which also trailed significantly in growth 4.5 months after planting.

The most promising medium we have tested for washability and nutritional efficiency is calcined clay, sometimes called baked clay. It is produced by heating natural clay so hot that organic matter burns away and the microporous structure of the clay is solidified. After baking, the clay is ground to any desired granular or powdered size. The end product looks like ground clay flower pots.

Our tests compared pure and mixed media consisting of fine sand, coarse sand, and two grinds of calcined clay: 15/30, which means the granules will pass through a screen of 15 mesh per inch but be retained by a 30-mesh screen (similar to coarse sand); and a coarser grind, 8/20, which will pass an 8-mesh screen but not a 20-mesh screen.

The 15/30 calcined clay was impressively efficient in dispensing applied nutrients to the seedlings, satisfactory in retaining moisture, and easily washed. It remained so when mixed as high as 1:1 with fine sand, but became droughty if mixed with coarse sand. The 8/20 calcined clay was too droughty either alone or in mixture.

Our work with calcined clay is preliminary, but it appears likely that the 15/30 grind could be an efficient, washable, reusable medium for eucalyptus seedlings.

An easily washed medium also washes easily through container drainage holes during irrigation or rainfall--or even runs unaided like sand through a funnel. Yet the container must have open-bottom drainage to direct roots down and out for air pruning.

My current efforts with washed seedlings are concerned with designing, building, and testing prototypes of containers that will permit air pruning of roots while retaining the washable medium. The wedge-shaped container used in the 1973 trial accomplishes those functions with a slot at the bottom of the wedge. The slot is 1/20 inch wide and as long as the wedge is wide, 2.2 inches in that particular design. The 1/20-inch slot retains fine sand with insignificant leakage while still allowing roots to egress for air pruning. A wider slot of 1/10 inch will retain moist but not dry calcined clay 15/30.

Containers can also be envisioned with bottoms or sloping sidewalls made of mesh materials or slitted and expanded materials.

The problem of retaining washable media in air-pruning containers is clearly solvable, but current development efforts are too preliminary to discuss in detail. Similarly, work on systems for operational washing--seedling extraction from cavities, recycling wash water and medium--must await container development.

For the indefinite future, the Florida eucalyptus program will continue to depend on plugs. We are swamped in efforts to increase plug production by solving technical problems in seed production, precision sowing, and plug fertilization. Consequently, progress is frustratingly slow in further assessing the potential of washed seedlings. But it is my hope that this cursory look at washed seedlings will result in pooled efforts with other interested workers who are seeking ways to break the size barrier in containerization.

LITERATURE CITED

Meskimen, George
1973. "Washed" eucalyptus planting stock--combining containerization with bare-rooting. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-190, 8 p.

Question: Are herbicides being used in field plantations to reduce competition?

Meskimen: No. Herbicide experience is available for controlling weeds on thousands of acres of abandoned vegetable lands in southwest Florida. But these are not yet being planted to trees. When we clear raw land in the palmetto-prairie type, we normally have 3 months of reasonably weedfree conditions. In wet years, the competition develops sooner, but if everything is done right, a stand can be established by use of large seedlings.

Question: Why not grow bare-root stock since survival is high for all kinds of trees?

Meskimen: Growing bare-root eucalyptus stock is not an easy matter. The seed is extremely tiny--about the size of pepper grains. It's very difficult to sow, both in open seedbeds and in containers. The survival of bare-root stock from open seedbeds is extremely unreliable; it varies unpredictably, averaging no better than 60 percent. Because of their normal rooting habit, it's hard to get good root systems on eucalyptus in open seedbeds. Perhaps some sophisticated root pruning, as done with the New Zealand root pruner, might aid us.